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F. K. Hare

CANADIAN FORESTRY SERVICE

Statements on
Long-Range Transport of Air Pollutants and Air Pollution Studies

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Prepared for the
1985 Edition of the Canadian Research Catalogue

Earth Sciences Library

P.J. Rennie
Canadian Forestry Service
Ottawa

October 1985

CANADIAN FORESTRY SERVICE

**Statements on
Long-Range Transport of Air Pollutants and Air Pollution Studies**

**Prepared for the
1985 Edition of the Canadian Research Catalogue**

**P.J. Rennie
Canadian Forestry Service
Ottawa**

October 1985



MEMORANDUM

NOTE DE SERVICE

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DATE

15 October 1985

SUBJECT LRTAP/Air Pollution: Canadian Forestry Service, CFS-Collaborative and
OBJET CFS-Sponsored Studies; Statements Prepared for the Canadian Research
Catalogue, 1985 Edition

Canadian Forestry Service scientists have prepared Project Statements for the 1981, 1983 and 1985 Editions of the Canadian Research Catalogue. These contributions are much appreciated and the Catalogue enjoys very wide Canadian and international distribution.

The publication of the 1985 edition is expected shortly and copies will be distributed to you. On this occasion, however, the CFS component will also be available as a separate package. This could be useful not only to CFS scientists in widely separated locations, but also as a portrayal of the over-all CFS Program in this topic. We are frequently asked what the CFS is doing in air pollution and have a need for an up-to-date document that is reflective of our concern and accomplishments.

In sending you the CFS component in the form of the attached Report, it may be explained that included are three types of project statements. First, those describing studies being conducted in-house by CFS scientists; secondly, those collaborative to varying degrees with other authorities and agencies; and thirdly, those being conducted by other authorities under contract to the CFS.

The project statements are grouped by CFS Establishments, starting with HQ, then moving from the east to the west. The order is, therefore, Maritimes Forestry Centre, Laurentian FC, Great Lakes FC, Northern FC, and Pacific & Yukon FC. The names of the principal scientists and authorities involved are indicated on each Establishment cover-page.

Individual statements vary in length and detail, reflecting the particular project and scientist's style, but two from HQ for the over-all Program and for the Early Warning System are more embracing because they provide background perspective and cohesion.

Additional copies are available.

P.J.R.
Chairman, Terrestrial Sector
CFS Air Pollution Program



MEMORANDUM

NOTE DE SERVICE

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Le 15 octobre 1985

SUBJECT
OBJET

TCGPA/Pollution atmosphérique: Etudes collaboratives et parrainées par le SCF; énoncés préparés pour le catalogue de la recherche du Canada, édition 1985

Les scientifiques du Service canadien des forêts (SCF) ont préparé des énoncés de projets pour les éditions de 1981, 1983 et 1985 du catalogue de la recherche au Canada. Ces contributions sont appréciées et le catalogue est l'objet d'une vaste distribution canadienne et internationale.

La publication de l'édition 1985 devrait paraître sous peu et des exemplaires vous seront envoyées. Pour cette occasion, toutefois, la partie relative au SCF sera disponible sous couvert séparé, ce qui sera utile non seulement aux scientifiques du SCF travaillant dans des endroits éloignés les uns des autres, mais aussi pour présenter une vue d'ensemble de tous les programmes du SCF sur ce sujet. On nous demande souvent ce que le SCF fait pour la pollution de l'air et avons un besoin d'un document à jour qui reflète nos problèmes et nos accomplissements.

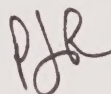
En vous envoyant le texte concernant le SCF sous le format du rapport ci-joint, nous pourrions expliquer qu'il comprend trois genres d'énoncés de projets. Premièrement, ceux qui décrivent les études conduites par les scientifiques du SCF; deuxièmement, ceux qui s'alignent à divers degrés avec les travaux d'autres autorités ou agences; et troisièmement, ceux qui sont menés par d'autres autorités liées par contrat avec le SCF.

Les énoncés de projets sont regroupés par établissement du SCF, commençant avec l'AC, et ensuite de l'est à l'ouest, suivant cet ordre: centre forestier des Maritimes, centre forestier des Laurentides, centre forestier des Grands Lacs, centre forestier du Nord et centre forestier du Pacifique et du Yukon. Les noms des principaux scientifiques et autorités concernés sont indiqués sur la page couverture de chaque établissement.

.../2

Des énoncés individuels varient en grandeur et en détail, reflétant les projets particuliers et le style du scientifique, mais deux énoncés de l'AC pour les programmes globaux et pour le Early Warning System (EWS) sont encore plus compréhensifs parce qu'ils fournissent une perspective historique et une certaine cohésion.

D'autres exemplaires sont disponibles.



P.J.R.

Le président du secteur terrestre
Programme TGDPA du MDE

Les données individuelles varient en grandeur et en détail,
résumant les projets particuliers et les styles de rédaction, mais
donc énoncés de l'AC pour les programmes généraux et pour la partie
training system (EVS) sont encore plus compliqués parce qu'ils
font partie d'une perspective historique et non d'un simple résumé.
L'ensemble des données sont disponibles.

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Provincial Agencies

TITLE: Canadian Forestry Service Air Pollution Program
(overall description for a Program conducted at various CFS Establishments
in collaboration with university, industry, provincial and other federal
agencies in Canada and elsewhere)

PRINCIPAL INVESTIGATOR

NAME: P.J. Rennie
P.A. Addison

PHONE: (819) 997-3350

AGENCY & DEPARTMENT:

Canadian Forestry Service

ADDRESS: Canadian Forestry Service
Ottawa, Ontario K1A 1G5
Canada

COOPERATION AGENCIES AND INVESTIGATORS

(if applicable):

Atmospheric Environment Service, Environment Canada
Environmental Protection Service, Environment Canada
Inland Waters Directorate, Environment Canada
Canadian Wildlife Service, Environment Canada
Land Directorate, Environment Canada

Soil Chemistry & Biology Institute, Agriculture Canada
Land Resource Research Institute, Agriculture Canada
Geological Survey of Canada, Energy, Mines & Resources
Department of Fisheries & Oceans

Provincial Resource Departments
Provincial Environment Departments
Alberta Acid Deposition Program
Provincial/Federal Research & Monitoring Coordinating Committee
Main Committee and Terrestrial Effects Sub-Group

Various university authorities - UNB, Laval, UBC, Toronto, McGill (Macdonald
College), Bristol, Aberdeen, Lancaster, Giessen, Göttingen, Munich, Freiburg,
Uppsala, North Carolina SU.

Ontario Hydro
Canadian Electrical Association
Canadian Pulp & Paper Association
Canadian Institute of Forestry
Pulp & Paper Research Institute of Canada
Noranda, Environmental Services
MacMillan Bloedel, Research & Development
Domtar, Research & Environmental Technology

United States Department of Agriculture, Forest Service
Environmental Protection Agency
American Paper Institute
National Council of the Paper Industry for Air & Stream Improvement
American Forestry Association
Society of American Forests
Electrical Power Research Institute

FRG Ministry of Food, Agriculture & Forestry
Federal Research Institute for the Forestry & Timber Industries
Nuclear Research Centre, Karlsruhe
FRG Ministry of Science & Technology
North-Rhine Westphalia Institute for Protection against Environmental
Pollution

INRA, Centre des Recherches, Campenoux
INRA, Centre des Recherches, Orléans
INRA, Ministry of Agriculture

Subsecretaria Forestal, Instituto Nacional de Investigaciones Forestales,
Mexico City

British Forestry Commission
Macaulay Institute for Soil Research
Institute for Terrestrial Ecology
Central Electricity Generating Board, Research Division
Swedish Environmental Protection Board

North American Forestry Commission, FAO

Atmospheric Deposition Study Group

UN, Economic & Social Council, Economic Commission for Europe (ECE)

Interim Executive Body (EB) for the Convention on Long-Range Transboundary
Air Pollution: Working Group on Effects of Sulphur Compounds on the
Environment

UN, Economic Commission for Europe (ECE), ECE/FAO Agriculture and Timber
Division. FAO European Forestry Commission, ad hoc Working Group "Impact
of Air Pollution on Forests".

DURATION:

Continuing, 1980 and earlier to at least 1990.

APPROXIMATE COST (PER YEAR):

Overall, the resources assigned to the Program are 12 professional person-years (pys) and 13.4 support pys. Annual pay for these pys amounts to over \$1,000,000. Annual operating and maintenance costs from the regular CFS research budget total \$500,000 with the possibility of an additional \$300,000 being derived from a special federal LRTAP allocation. Capital items are budgeted separately and there are elements of other Programs - the Forest Insect & Disease Survey Organization; the Forest Statistics and Systems Branch - that contribute without fiscal charge.

PROJECT OBJECTIVES/DESCRIPTION/THE PROBLEM/BACKGROUND

Canadian Forest Resources - Extent and Value

The total land area of Canada is 909 million hectares. Only 326 million hectares (36 per cent) of this total are classified as productive forest and at the present time only 161 million hectares (18 per cent) are economically accessible.

The 1980 forest harvest was obtained from 760,000 hectares and yielded 145 million cubic metres. The average yield, therefore, is 190 cubic metres per hectare, amounting to a productivity of 1.9 cubic metres per hectare per year if a 100-year rotation is assumed.

The annual shipped value of wood products is \$23 billion and the net currency earned from their export is \$13 billion, reflecting the outstanding economic and social values of forests to Canada. In addition, both the productive forests and the slower-growing non-commercial forests have incalculable indirect values. They provide shelter and habitat for numerous species of wildlife, they stabilize soil against erosion, they preserve the quality of water and fish habitat, and they support extensive recreational and tourist activities.

Seventy-nine per cent of the Canadian forest is coniferous and 80 per cent is boreal, a continental climate and nutrient-poor soils combining to limit productivity. The forest is semi-natural and the traditional absence of intensive management means that forests always contain a proportion of dead and dying stems associated with the natural thinning process. This important difference to intensively managed European forests must be understood if valid inter-continental comparisons are to be attained.

The Air Pollution Threat

Some 39 million hectares, or 55 per cent, of the total of 71 million hectares of the productive forest of eastern Canada receives acid precipitation at a level exceeding 20 kilograms of wet sulphate per hectare per year. This affects southern Ontario and Quebec, the three Maritime Provinces, and about half of Newfoundland. In southwest Ontario, parts of the St. Lawrence River valley, and southeast Quebec values exceed 40 kilograms of wet sulphate per hectare per year. "Dry" deposition of sulphate is thought to amount to about another 60 per cent of wet figures. In addition, there is acid nitrate deposition which ranges from 10 to 30 kilograms of wet acid nitrate per hectare per year over a somewhat smaller eastern Canadian area.

In western Canada, an area of possibly some 7 million hectares receives acid precipitation at a level exceeding 20 kilograms of wet sulphate per hectare per year. This is centred on Vancouver Island and includes part of the Coast Range east and north of the Island. It has to be emphasized that although the 20 kilogram level is claimed to constitute a threshold for the initiation of lake acidification in sensitive terrain, there are no data able to assess the significance of this level for forests.

With regard to injurious ambient concentrations of pollutants, there has been a history of such occurrences for sulphur dioxide around strong point sources of emission, but the development of high-stacks and other technology has reduced this problem to very local proportions. Nevertheless, formidable quantities of air pollutants are still emitted into the atmosphere and these contribute to the more widespread and regional impairment of air quality.

Thus, sulphur dioxide and nitrogen oxide emissions for Canada are 4.5 and 1.9 million tonnes per year respectively, whilst the emission of much larger totals upwind means that Canada is a net importer of airborne pollutants. Networks are not well developed for ozone, but it is known that episodes of phytotoxic concentrations occur in southern Ontario, in the Windsor, Ontario to Quebec City corridor, in the greater Vancouver area, and in urban centres, but in the absence of more precise monitoring networks it is thought that the more southerly mixedwood Canadian forests may experience adverse ozone concentrations, but perhaps not the main predominantly coniferous forest areas.

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As might be expected, comparisons have been made between Canada on the one hand and Scandinavia and Central Europe on the other. Canadian air pollution levels seem to resemble those of Central Sweden, with possibly the southernmost parts of Canada being exposed to levels comparable to southern Sweden. Ambient concentrations of sulphur dioxide and ozone in Canada, as well as deposition levels of sulphate and nitrate, are considerably less than in Central Europe.

Forest Damage Characteristics

It is sometimes difficult for the observer accustomed to the clinical well-being of the intensively managed European forest to adjust to the very different characteristics of the normal but semi-natural Canadian forest.

Although the nature of forest management is changing and some features will not be unfamiliar, such as site preparation, planting, crop protection, shorter rotations and more complete harvesting, other features will strike a sharp contrast. These include the extensiveness of forests, often overmature, comprising very few species, the scale of clearcutting with an absence of periodic thinning, widespread fires, and a prevalence of highly damaging insect and disease epidemics.

Combined with a natural site heterogeneity that results in patches of forest being distributed on very poor or shallow soil, these features give rise to a proportion of trees that are unthrifty and which in the European setting might be explained by some exceptional stress factor, such as air pollution. The Canadian statistics convey very well the threats and losses that form part of the natural scene. Annual fire losses amount to 2.1 million hectares of forest - three times the area harvested! Pests and diseases give rise to annual losses of 107.4 million cubic metres - 74 per cent the size of the annual harvest. From one pest alone, spruce budworm, there were 25.2 million hectares of forest dead or dying in 1982. And through inadequate restocking after clearcutting there is an accumulated total of 17.8 million hectares of prime forest land in need of rehabilitation.

The important point is, therefore, that the Canadian forest displays abundant examples on all sides of declines, diebacks and unthriftness. They are mostly part of the natural scene and have been around a long time. Sometimes their symptomology resembles air pollution damage and can be confused with it.

The Canadian task is to try and separate the traditional forest diebacks from those that might be occurring through air pollution. This task is made more difficult when some diebacks may be caused by a combination of stress factors. But this is the reason why, in the present setting in Canada, the attack is being mounted through both the "National Early Warning System" and through an accompanying program of research studies. Both are described in separate Study Statements.

Current Estimates of Forest Damage

The most careful and regular scrutiny of Canadian forests by specialists of the Forest Insect and Disease Survey Organization has revealed no discernible effects ascribable to regional air pollution, except near strong point sources of emission. For this latter situation it has been estimated that from 1.1 to 2.5 million hectares of forest would have been affected to a greater or lesser extent.

In a separate and special category is the dieback reported for sugar maple (Acer saccharum Marsh.) in parts of the mixedwood and hardwood zones of southern Ontario and Quebec. Although these areas are the most polluted in Canada, they are relatively lightly polluted compared with central Europe. The problem is complex and the evidence for a causal link between air pollution and sugar maple decline does not exist. The forest stands are managed for sugar maple and the trees tapped regularly for sap. It is widely agreed a number of stress factors could be involved. These include drought and other exceptional weather patterns, insects, diseases, site conditions and management. Not all sugar maple is affected and hardwoods in the past in eastern North America have shown periodic declines. A particularly serious dieback affected yellow birch (Betula alleghaniensis Britton) and other hardwoods in much of eastern North America during the 1930 to 1950 period. A feature of some of the sugar maple in the current decline is that their nutrition seems disturbed, both the foliage and soils exhibiting values below levels of adequacy.

Causes for Concern

Although no discernible regional effects of air pollution have been demonstrated seven main reasons give cause for concern and provide the rationale for the Program.

First, Canadian forests are of unparalleled economic, social and environmental value - the more so northern temperate ones where there are no alternative land uses, and in the light of the fact that warm temperate and tropical forests are being lost at the rate of 11 million hectares per year.

Secondly, it is well known that strong point sources of air pollution and acidifying soil fertilizers can impair forests and degrade soils.

Thirdly, constantly improving pollutant emission and deposition data provide unsuspected information about new threats and indicate more precisely the very extensive areas of forests being impacted.

Fourthly, pollution levels are at a level over considerable areas of forest sufficient to cause changes in lakes and rivers. Such changes must involve associated changes in the forest soils. Although these may not yet be harmful they could well be so sooner or later. They are early warnings.

Fifthly, although tree-growth impairment has not so far been demonstrated for Canada and Scandinavia, this is not the situation in Central Europe where air pollution is suspected of having been a contributory factor. Moreover, there is a suspicion that some Scandinavian soils have decreased in base status at a rate faster than that attributable to a developing forest stand.

Sixthly, there is good evidence that many forest soils are accumulating heavy metals at a rate sufficient to raise serious questions about the continued well-being of soil microorganisms.

Seventhly, our general understanding of the ecological principles underpinning forest growth - especially with regard to the demands of production, the interactions of stress factors, and the reduced resistance of forests to insect and disease attack when exposed to multiple stresses - causes us to take the threat of air pollution very seriously and to design an appropriate research program to assess the significance of this threat.

CFS Air Pollution Program

The CFS has researched air pollution problems in forestry since the 1930s. From the late 1970s the program has expanded considerably. It embraces regional in addition to strong point source problems, and now forms part of a collaborative federal, provincial and international endeavour involving meteorological, aquatic, fisheries, wildlife, and agricultural interests.

CFS Program Objectives

Unlike the forest situation in Central Europe and parts of the Appalachians where there is obvious growth decline, that in Canada - as in Scandinavia, where there is no obvious decline ascribable to regional air pollution - poses special difficulties.

Broad research objectives include:

- establishment of baselines for future comparisons,
- elucidation and analysis of trends in annual incremental growth,
- monitoring the forest for growth disorders and other changes,
- development of dose/response relationships,
- evaluation of ceiling deposition levels or pollutant concentrations permitting continued well-being and productivity of forest.

The Program is conducted at several Forest Research Centres across Canada. Program approaches include both field and laboratory studies. A main field installation comprises three main forest catchment basins where the aim is to prepare long-term hydrological and nutrient budgets. Such budgets are essential to show the impact of deposited pollutants and their distribution in representative forest ecosystems. Laboratory studies include testing the direct effects of simulated acid rain upon such characteristics as tree-seedling growth, root-mycorrhizal development, rootlet mortality and reproductive processes. Indirect effects investigated include solubilization of soil aluminum, accelerated loss of soil nutrients and soil-nitrogen transformations. The details of these and other studies are described in the following Study Statements. Two special Program developments warrant additional general comment - ARNEWS and the DENDRON study.

The first - ARNEWS - has involved the setting up of the Acid Rain National Early Warning System (ARNEWS). It is an extension of Canada's highly respected FIDS Unit. On over 100 permanent sample plots located in representative forests across Canada, the regular monitoring of forest health is being supplemented by special soil and vegetation analyses designed to detect possible changes. Canada as a member of both European and North American Forestry Commissions of FAO has contributed this expertise to the development of methodologies that have been adopted by over 20 European countries and which are currently being incorporated into the United States' National Vegetation Survey.

The second is a dendrochronological study. The recent revelation that there had been growth decline in Central European and Appalachian forests for some 20 or more years before the appearance of obvious visual ills prompted the CFS to mount an especially sensitive dendrochronological investigation. One of Canada's top forest consultancies has been contracted to examine radial incremental growth of important species across the zone of pollutant deposition in eastern Canada. Exceptional growth decline occurring in the past 50 or more years should be detectable and the cause further investigated.

Program Relationships

A few words may help to explain the way the organizations listed above collaborate in the implementation of the CFS Program. At the Canadian provincial level the CFS maintains its traditional links with provincial resource departments. There is another provincial linking mechanism, however, organized through a special federal/provincial Acid Rain Research & Monitoring Coordinating Committee (RMCC), co-chaired by the ADM, AES, representing the entire federal Acid Rain Program and an ADM of Ontario MOE, representing provincial Acid Rain programs conducted through provincial Environment departments. The main RMCC meets twice-yearly and with its NAPAP (National Acid Precipitation Assessment Program) counterpart in the United States annually. CFS is represented on the RMCC and provides a co-chairman on the RMCC Sub Group, the Terrestrial Effects Sub Group (TESG), which embraces forests, soils, agriculture and terrestrial wildlife. There is a corresponding Terrestrial Task Group in the U.S. NAPAP Structure, but CFS is aware of its activities mainly through direct CFS contacts with the USDA Forest Service chairman rather than through the TESG.

At the federal Canadian level, AES is the lead agency for the federal research program and a LRTAP Liaison Office (LLO), run from AES HQ, has exercised an over-all coordinating role. CFS, and other agencies, provide details through sector representatives of their Acid Rain studies, expenditures, progress, etc., and contributed substantially to the Royal Society of Canada Peer Review of the federal program organized by LLO. LLO has a difficult task synthesizing other agencies' specialist material, but it is essential for CFS to contribute requested material, otherwise viewpoints in forestry are developed without CFS input.

At the bilateral level and arising from the Mulroney/Reagan meeting of March 1985 was the decision to set up a bilateral Acid Rain Office (ARO) with high-level envoys from each federal government. Deputy Ministers of the federal departments conducting acid rain studies met on 27 June to develop terms of reference for the science program and for ARO.

There is one further formal federal Canadian link. For abatement strategies and the development of overall program, EPS is the lead agency and consults with External.

At the international level there are in addition to innumerable international contacts, three more formal arrangements. One is a lead role in the formation of a new Atmospheric Deposition Study Group set up under the aegis of FAO's North American Forestry Commission. Representatives of the three countries; Mexico, the United States and Canada have been nominated, draft terms-of-reference prepared, as well as initial tasks, and an inaugural meeting is scheduled for late 1985.

The second accord is represented by CFS representation on FAO's ECE Agriculture and Timber Division, specifically the ad hoc Working Group "Impact of Air Pollution on Forests" set up with the European Forestry Commission. This Working Group now works jointly with the Working Group on the Effects of Sulphur Compounds on the Environment set up by the Executive Body of the 1979 Convention on Long-Range Transboundary Air Pollution. Through this the CFS made a notable contribution to the June 1984 and October 1985 Meetings hosted in Freiburg by the West German Ministry of Food, Agriculture and Forestry. From these meetings a framework monitoring and assessment protocol was developed and applied by over 20 countries. As it is also used in Canada's ARNEWS network intercomparability will be ensured among North American and European forestry agencies for estimating forest damage.

The third accord comes under the aegis of the 1971 FRG/Canada Agreement of Scientific and Technical Cooperation. From this accord literature is regularly exchanged and a special CFS Mission to West Germany was organized in October 1984. The tour provided FIDS and other scientists with first-hand experience of dieback symptoms for incorporation into CFS monitoring. Arrangements are also being made to develop collaborative projects in areas of mutual benefit. These include early physiological indicators, effects of pollutant mixtures, and soil-nitrogen transformations.

Program Context: Emission Control Scenario

Sulphur dioxide emissions are around 21 million tonnes in the U.S. and 4.5 million tonnes in Canada. It is estimated that about half of the acid sulphate deposited in eastern Canada comes from the U.S. and that a 50 per cent over-all reduction of emissions would bring deposition levels in eastern Canada down to less than 20 kg wet sulphate per ha per year, which is claimed by Canadian aquatic scientists to be a threshold level for the onset of extreme acidification in sensitive Canadian lakes.

Although no bilateral agreement has been reached to implement such a 50 per cent reduction, progress has been made under the 1979 UN ECE Convention. As a result of the 1982 Stockholm meeting, the Convention was ratified by the required number of countries in March 1983. From the Ottawa Conference of March 1984 came the agreement by nine European countries plus Canada to cut SO₂ emissions by 30 per cent by 1993 using 1980 levels as the basis. More countries agreed to this 30 per cent cut at a June 1984 meeting in Munich. By this date, however, Canada had decided to implement a unilateral cut of 50 per cent in SO₂ emissions by 1994, based on 1980 emissions, and there is a federal/provincial accord of February 1985 showing how the cut from 4.5 million tonnes to 2.6 million tonnes will be distributed among provinces and among industry sectors - smelters, utilities and other sources. An important part of the CFS Program will be to monitor the forest ecosystems in the context of this abatement.

CFS Program Accomplishments:

In the past 10 years, some 180 high-calibre papers have been published in the scientific literature. Some are major reviews establishing for CFS scientists positions of national and international stature. Substantial contributions were made to the 1982 Stockholm Conference, to the 1984 and 1985 Freiburg Workshops and to the 1984 Royal Society of Canada Peer Review. A major international Conference on "Acid Rain and Forest Resources" was organized in Quebec City in June 1983 in collaboration with the USDA Forest Service. A critically important aspect of CFS air pollution scientists is their reputation for objectivity in a setting where well established facts are few and unsubstantiated and exaggerated claims abundant.

Recent Trends

Critical examination of the acid rain phenomenon shows it to be complex and for forests far from being solved with regard to effects, causes, and required abatement. Interest has shifted very much to:

- (1) cuticle integrity and hidden physiological effects for direct effects,
- (2) mixtures of pollutants especially ozone rather than just wet sulphate, and
- (3) the role of soil interactions in site impoverishment for indirect effects.

The expanded resources secured for 1985-90 will permit emphasis in these areas either in-house or through appropriate university or other agency expertise. A special Delphi-type opinion survey addressed to some 35 North American scientists has confirmed the concern that the CFS feels about the threat of air pollution. The survey indicated that growth declines may already be underway and could continue if abatement is not implemented.

-"-

L.F. Hogg
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M1R 3P7

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Timber Lake, Ont.
M1R 3P7

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LOCATION: The project is located in the Great Lakes region of North America.

APPROXIMATE COST: The project is estimated to cost approximately \$100,000.

OBJECTIVES: The objectives of the project are:

1. To develop the potential for forest site assessment and site classification by using remote sensing data and ground-based data.

2. To develop a system for site assessment and site classification using remote sensing data and ground-based data.

CONCLUSION: A system of site assessment and site classification using remote sensing data and ground-based data has been developed. The system is based on the use of remote sensing data and ground-based data.

TITLE: "Acid Rain" National Early Warning System

PRINCIPAL INVESTIGATOR'S NAME: E.S. Kondo

AGENCY AND DEPARTMENT: Canadian Forestry Service

ADDRESS: Place Vincent Massey
Ottawa, Ontario
K1A 1G5

PHONE: 819-997-2269

COOPERATING AGENCIES

AND AGENCIES:

G.A. Van Sickle
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Canadian Forestry Service
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Victoria, B.C.
V8Z 1M5

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J. Hudak
Newfoundland Forest Research Centre
Canadian Forestry Service
P.O. Box 6028
St. John's, Newfoundland
A1C 5X8

Together with appropriate provincial agencies.

DURATION: Program commenced in 1984 and is designed for long term (20 years) monitoring

APPROXIMATE COST: \$80,000/ per annum with additional extensive sample collection and analysis costs every five years of \$50,000.

OBJECTIVES: The objectives of the program are:

1. To detect the possible damage to forest trees and soils caused by acid rain or to identify the damages sustained by Canadian Forests (trees and which are not attributable to natural causes or management practices;
2. Long term monitoring of vegetation and soils to detect future changes attributable to acid deposition and other air pollutants in representative forest ecosystems.

METHOD: A network of plots, together with the integration of available information from all sources on acid rain and air pollutants in Canada, has been termed the Acid Rain National Early Warning System (ARNEWS). It was established in 1984.

Over 100 permanent plots are maintained in all regions of Canada to monitor:

1. the condition and changes in the conditions of the forest stand;
2. the presence and fluctuation of biotic and abiotic factors that affect the condition of the forest (insects, diseases, stand changes, temperature, etc.);
3. the changes and symptoms that indicate factors not attributable to the above that could conceivably be early signs of acid rain damage;
4. effects of acid rain on the condition of the various economically important tree species.

The Canadian Forestry Service's Forest Insect and Disease Survey (FIDS) organization distributed across Canada, is responsible for establishment and monitoring of the plots. Broadly, one of the ongoing functions of FIDS is the early detection, monitoring and evaluation of forest growth disturbances. Specifically the FIDS' role is to bring to light and map tree-growth disorders caused by pollutant stresses, climatic abnormalities, and insect and disease attacks. Thus it is only natural that FIDS should coordinate the National Early Warning System for "Acid Rain" damage to Canada's forests.

ANTICIPATED RESULTS:

It is hoped that with the collection of baseline data and the close monitoring of all "pertinent" factors on permanent plots over a period of time subtle effects of "acid rain" can be identified to provide early warning of possible damage to Canada's forests.

LRTAP PROJECT DESCRIPTION

TITLE The Potential Impact of the Long Range Transport of Air
Pollutants on Canadian Forests

PRINCIPAL INVESTIGATOR

NAME: G. Alex Fraser

PHONE: 997-1683

AGENCY & DEPARTMENT: Canadian Forestry Service

ADDRESS: Place Vincent Massey

COOPERATION AGENCIES AND INVESTIGATORS University of Alberta: Dr. W.E. Phillips
Dr. G.W. Lamble
(IF APPLICABLE): also, A.G. Teskey and Gary D. Hogan

DURATION: Completed 1985

APPROXIMATE COST (PER YEAR): Total Cost: 100K

PROJECT OBJECTIVES/DESCRIPTION The intent of the project was to solicit and aggregate informed scientific opinion on the potential adverse impacts of LRTAP on Canadian forests. This was done using an iterative series of 4 questionnaires interspersed with summarised feedback and opinions from previous responses. Opinions were solicited on the nature, extent and likelihood of alternative forest productivity effects both at present and into the future. Opinions on future effects were solicited under the assumption of several different pollution levels.

LRTAP PROJECT DESCRIPTION

TITLE Damage Vulnerability Index

PRINCIPAL INVESTIGATOR

NAME: Alan G. Teskey

PHONE: 997-1683

AGENCY & DEPARTMENT: Canadian Forestry Service

ADDRESS: Place Vincent Massey

COOPERATION AGENCIES

AND INVESTIGATORS G. Alex Fraser

(IF APPLICABLE):

DURATION: Completed 1986

APPROXIMATE COST (PER YEAR): Total Cost: 25K

PROJECT OBJECTIVES/DESCRIPTION The objective of this project is to geographically delineate the vulnerability of the forest industry to net sulphate and nitrate deposition. Information on deposition levels, soil buffering capability and species sensitivity are being intergrated into a vulnerability index. A series of vulnerability classes will then be mapped using the information base of the Canadian Forest inventory. This forest resource information will then be intergrated with census information on forest industry location and socio-economic characteristics. This will shed light on the potential regional impacts of LRTAP damage on a sub-provincial basis.

LRTAP PROJECT DESCRIPTION

TITLE The Forestry Benefits of Long Range Air Pollution Control

PRINCIPAL INVESTIGATOR

NAME: G. Alex Fraser

PHONE: 997-1683

AGENCY & DEPARTMENT: Canadian Forestry Service

ADDRESS: Place Vincent Massey

COOPERATION AGENCIES

AND INVESTIGATORS N/A

(IF APPLICABLE):

DURATION: Phase I: Completed 1985

Phase II: Undetermined

APPROXIMATE COST (PER YEAR): Phase I: 20K

Phase II: Undetermined

PROJECT OBJECTIVES/DESCRIPTION Phase I: The intent of phase I is to obtain a preliminary estimate of the social and economic benefits (in the area of commercial forestry) to be derived from the control of long range air pollution. Step one involves using the results of the CFS expert opinion survey to delineate the nature and potential range of forest productivity impacts with and without pollution control. Step 2 involves determining the implications of forest productivity changes for future harvest levels with and without pollution control. Step 3 involves estimating the social and economic value of the difference in harvest rates with and without pollution control.

Phase II: The preliminary estimate in phase I incorporates numerous simplifying assumptions regarding economic variables. Phase II would incorporate more rigorous modelling of forest product markets in order to determine impacts on forest product prices and the distribution of benefits between producers and consumers. Other elements of phase II would include an assessment of the non-pecuniary forestry benefits of long range air pollution control (such as recreational and aesthetic benefits.) Also, benefits to be derived from annual tree cropping activities, such as maple sugar production, could be assessed.

PROJECT NUMBER : 412

PROJECT CODE : 1.2.2

TITLE : INVESTIGATIONS OF SOIL pH AND NITROGEN TRANSFORMATION
TENDENCIES

PRINCIPAL INVESTIGATOR'S NAME : M.K. Mahendrappa

AGENCY AND DEPARTMENT : Agriculture Canada
Canadian Forestry Service - Maritimes

ADDRESS : P.O. Box 400
Fredericton, N.B. A3B 3e7

PHONE : (506) 452-3049

COOPERATING INSTITUTION : Maritimes Forest Research Centre

M.K. Mahendrappa
K.E. Percy
P.O. Salonijs
R.M. Cox
G.D. van Raalte
H. van Groenewoud

COOPERATIVE INSTITUTION : University of New Brunswick

E.A. Baker
P.J. Holloway
Long Ashton Research Station
University of Bristol

METHOD : An investigation of soil pH and nitrogen transformation in the forest and open areas of the Maritimes region, and the effect of these interactions with soil pH and

A.R. Wellburn
University of Lancaster
I.A. Nicholson
F.T. Last
Institute of Terrestrial Ecology
H.J. Jaeger
Justus-Liebig Universitat
Giessen
Ontario MOE

ANTICIPATED RESULTS :

A number of forest publications are available and
are being prepared.

PROJECT NUMBER : 318

SUBJECT CODE : 3.2.2

TITLE : Interactions of Acid Rain and Nitrogen Transformation Processes

PRINCIPAL INVESTIGATOR'S NAME : M.K. Mahendrappa

AGENCY AND DEPARTMENT : Agriculture Canada
Canadian Forestry Service - Maritimes

ADDRESS : P.O. Box 4000
Fredericton, N.B. E3B 5P7

PHONE : (506) 452-3549

COOPERATING AGENCIES AND INVESTIGATORS :

DURATION OF EACH PHASE : 1981-86

APPROXIMATE COST : 10K

OBJECTIVES : To characterize nitrogen transformation processes in the forest ecosystems of the Maritimes region, and to determine their interactions with acid rain and other pollutants.

METHOD : a) An incubation experiment to study N mineralization in organic materials affected, to different degrees, by SO₂ pollution.

b) Collect and evaluate data on nutrient cycling in eight forest stands in Acadia Forest Experiment Station (AFES), New Brunswick.

c) Monitor quality and quantity of open-rain, event samples collected at AFES.

ANTICIPATED RESULTS :

A number of journal publications are available and more are anticipated.

LRTAP PROJECT DESCRIPTION

TITLE Simulated Acid Rain Effects on the Plant Cuticle in Relation to
Foliar Uptake of Inorganic Ions.

PRINCIPAL INVESTIGATOR

NAME: Kevin Percy

PHONE:

AGENCY & DEPARTMENT: Canadian Forestry Service

ADDRESS: Permanent Address:

Maritimes Forest Research Centre
P O Box 4000
Fredericton, New Brunswick
E3B 5P7 CANADA

Current Address:

Long Ashton Research Station
Long Ashton
Bristol BS18 9DL
ENGLAND

COOPERATION AGENCIES

AND INVESTIGATORS

(IF APPLICABLE): Dr E A Baker, Long Ashton Research Station

DURATION: 1/9/85 to 1/9/87

APPROXIMATE COST (PER YEAR): \$5 K

PROJECT OBJECTIVES/DESCRIPTION

Plants of various crop species (3) and Sitka spruce (2 clones) will be exposed in a specially constructed, controlled environment rain tower to simulated rain of several acidities in order to induce various degrees of change in cuticular characteristics.

The plants will then be treated with mono-size droplets of various sizes produced with a specially designed microsprinter. The droplets will contain the radioisotopes ^{86}Rb , $^{35}\text{SO}_4$ and ^{63}Ni .

The following parameters will be studied:

1. Uptake of the isotopes in relation to changes in the cuticle induced by acid rain.
2. The localization of the isotopes within the epicuticular wax (structural and amorphous), the cuticular membrane, the epidermis, and the underlying leaf tissue.

LRTAP PROJECT DESCRIPTION

TITLE Effects of Simulated Acid Rain on the Plant Cuticle

PRINCIPAL INVESTIGATOR

NAME: Kevin Percy

PHONE:

AGENCY & DEPARTMENT: Canadian Forestry Service

ADDRESS: Permanent Address:

Maritimes Forest Research Centre

P O Box 4000

Fredericton, New Brunswick

E3B 5P7 CANADA

Current Address:

Long Ashton Research Station

Long Ashton

Bristol BS18 9DL

ENGLAND

COOPERATION AGENCIES

AND INVESTIGATORS

(IF APPLICABLE): Dr E A Baker, Long Ashton Research Station

Dr P J Holloway, Long Ashton Research Station

DURATION: 1/9/84 to 1/9/87

APPROXIMATE COST (PER YEAR): \$ 8K

PROJECT OBJECTIVES/DESCRIPTION

Plants of various crop species (5 +6 mutants) and Sitka spruce (2 clones) selected for their variation in cuticular characteristics will be exposed to realistic amounts of simulated acid rain (7 pH's) in a specially designed calibrated environment - rain tower.

The effects of rain treatment on the following aspects of the cuticle will be investigated:

1. Rate and amount of epicuticular wax production
2. Epicuticular wax morphology
3. Epicuticular wax chemistry
4. Cuticular membrane ultrastructure
5. Leaf wettability

PROJECT NUMBER : 342

SUBJECT CODE : 3.2.3

TITLE : Kejimikujik Catchments Study

PRINCIPAL INVESTIGATOR'S NAME : K.E. Percy

AGENCY AND DEPARTMENT : Agriculture Canada
Canadian Forestry Service - Maritimes

ADDRESS : P.O. Box 4000
Fredericton, N.B. E3B 5P7

PHONE : (506) 452-3532

COOPERATING AGENCIES AND INVESTIGATORS :

Dr. J.J. Kerekes, CWS

DURATION OF EACH PHASE AND APPROXIMATE COST :

In abeyance until 1987.

OBJECTIVES : a/b) To characterize the baseline condition of the forest vegetation and soils within the Beaverskin and Pebbleloggitch catchments in Kejimikujik National Park, N.S.

- c) To determine LRTAP and nutrient input into the catchments through the monitoring of non-intercepted and intercepted precipitation (stemflow and throughfall).
- d) To elucidate trends in the forest ecology of the catchments and identify any LRTAP effects through long-term continuous monitoring.
- e) To study the influence of the forest soils in the catchments on the quality of intercepted rainfall.

- METHOD : a/b) An intensive forest inventory will be completed. Forest soils in the catchments will be sampled and a chemical and physical analysis performed. Species composition, density, primary productivity and nutrient data will be generated for the tree, shrub, herb and mosslichen vegetation layers.
- c) Precipitation samples will be collected at least weekly with an event sampling period during the summer.
- d) Periodic resurvey of the plan-soil systems will be used to monitor long-term trends.
- e) Soil water will be periodically sampled from selected horizons underneath the precipitation chemistry study plots.

ANTICIPATED RESULTS :

A report detailing the baseline characteristics of the catchments will be prepared.

PROJECT NUMBER : 341

SUBJECT CODE : 3.2.3

TITLE : Direct Effects of Simulated Acid Rain on Forest Trees

PRINCIPAL INVESTIGATOR'S NAME : K.E. Percy

AGENCY AND DEPARTMENT : Agriculture Canada
Canadian Forestry Service - Maritimes

ADDRESS : P.O. Box 4000
Fredericton, N.B. E3B 5P7

PHONE : (506) 452-3532

COOPERATING AGENCIES AND INVESTIGATORS :

DURATION OF EACH PHASE : In abeyance until 1987

APPROXIMATE COST :

OBJECTIVES : a) To determine the interspecific sensitivity of at least fourteen eastern Canada forest tree species to simulated acid rain.

b) To initiate work on the morphology of individual species response, and to document alterations in plant form and development induced by acid rain.

METHOD : Various pHs (2.6, 3.6, 4.6, 5.6) of rain will be applied to tree seedlings at a rainfall intensity, volume and droplet diameter modelled on those measured at a forest site in central New Brunswick. Rain chemistry will be derived from 1980 growing season rain data collected at the same site.

ANTICIPATED RESULTS :

Data on the sensitivity of Acadian forest tree species to simulated acid rain in terms of germination, establishment and subsequent growth parameters will be published.

PROJECT NUMBER : 319

SUBJECT CODE : 3.2.2

TITLE : Interactions of Acid Rain and Forest Soil Organic Transformations

PRINCIPAL INVESTIGATOR'S NAME : P.O. Saloni

AGENCY AND DEPARTMENT : Agriculture Canada
Canadian Forestry Service - Maritimes

ADDRESS : P.O. Box 4000
Fredericton, N.B. E3B 5P7

PHONE : (506) 452-3548

COOPERATING AGENCIES AND INVESTIGATORS : K.E. Percy
CFS - Maritimes

DURATION OF EACH PHASE : Part-time

APPROXIMATE COST : \$500/year

OBJECTIVES : Investigate the effect of simulated acid rain on forest soil microbial activity.

METHOD : a) Forest soils will be treated with varying pHs of acid rain in laboratory simulated rainfall chambers.

b) Oxygen uptake patterns of the treated soils will be studied.

c) Ammonium and nitrate production will be investigated in modified soils after prolonged incubation.

d) Patterns of tree rings in areas differently affected by SO₂ will be evaluated as possible indicators of acid rain impacts on forests.

ANTICIPATED RESULTS : Data will be published.

PROJECT NUMBER:

SUBJECT CODE:

TITLE: Air pollution effects on reproductive processes in forest plants.

PRINCIPAL INVESTIGATOR'S NAME: R.M. Cox

AGENCY AND DEPARTMENT: Canadian Forestry Service - Maritimes

ADDRESS: Maritimes Forest Research Centre
P.O. Box 4000
Fredericton, N.B.
E3B 5P7

PHONE: (506) 452-3532

COOPERATING AGENCIES
AND INVESTIGATORS: -

DURATION OF EACH PHASE: 1985-1990

APPROXIMATE COST: 30 K/year (excluding salaries)

OBJECTIVES: To determine paternal and maternal influences in the sensitivity of the reproductive processes of forest plants to simulate air pollution in relation to habitat factors.

METHOD:

- 1) determine and relate variation of pollen response to acidity and trace elements within and between population with different site characteristics (base status).
- 2) determine pH and buffering capacity of pollination droplets and stigmatic surfaces in populations with different site characteristics.
- 3) initiate the development of gas delivery system to supply SO_2 and O_3 to small open topped branch tip fumigation chambers to test in vivo response of reproductive processes and resource allocation to seeds, to combination of air pollutants.

ANTICIPATED RESULTS:

- 1) An experimental protocol to examine the effect of various mixtures of gaseous and wet deposited air pollutants on reproductive processes and resource allocation in trees in the field.
- 2) To identify genetic variation in maternal and paternal contribution to air pollution sensitivity that may be useful for breeding resistant genotypes.

Study Statement

Title: Air pollution effects on reproductive processes in forest Plants.

Study Leader: R.M. Cox

Problem or Opportunity: Reductions in reproductive capacity of forest species due to air pollution have been well documented together with the sensitivity of pollen to ambient levels of acidity and trace metals. There is need to further understand not only how the reproductive processes of these species are affected by air pollution and what variation in sensitivity exists within and between populations but also to understand the consequences of micro-gametic sensitivity to these pollutants on future generations. Possible sources of variation in reproductive sensitivity are physiological tolerance of pollen, chemistry of pollination droplets or stigmatic surface and the nutrient and base states of pollen and mother. A study of these factors may identify useful maternal and paternal genetic variation that may be brought together in breeding programs to improve tolerance of at least the reproductive systems to air pollutants. Furthermore in the light of recent studies that may indicate as much as 60% of the genes expressed in the sporophyte are expressed in the pollen may lead to further evaluation of the pollen environment during pollination ie. pollen droplet or stigmatic surface of certain species for direct chemical manipulation. This may provide a means of artificial gametic selection to still further increase the frequency of genes contributing to tolerance of specific pollutants in the progeny of mothers that can be themselves a product of artificial selection. Gases such as SO_2 , O₃, and fluoride may be applied to reproductive structures in the field with an appropriate gas delivery system whereas trace metals and acidity may be applied in simulated acid rain by spray.

This research opportunity will allow a more accurate interpretation to the longterm impact of long range transported air-borne pollutants on fecundity of natural populations, seed production and quality in seed orchards and fitness of progeny. The combined use of sporophyte and gametophyte selection procedures may hasten the production of genotypes tolerant to air pollutants. These genotypes will be useful for urban forestry, maintaining seed production in seed orchards impacted by regional air pollution, maintenance of soil erosion control in polluted sites and for reclamation of local areas deforested by ongoing air pollution.

Long Range Plans

1. To perfect an experimental protocol to examine the effects of various mixtures of gaseous and wet deposited air pollution on reproductive structures and foliage of trees in the field.
2. To determine possible impacts of regional levels of ambient air pollution on fecundity and progeny fitness of certain important forest species.
3. To identify genetic variation in the maternal and paternal contribution to air pollution sensitivity that may be useful for breeding of resistant genotypes.

LRTAP PROJECT DESCRIPTION

TITLE:

Impact of Acid Rain on Forest Growth in Canada

PRINCIPAL INVESTIGATOR: (CONTRACTOR)

NAME: Dendron Resources Ltd.

AGENCY & DEPARTMENT:

This is a contracted study, Number 05C-84-00463, commissioned by the CFS. The scientific authority is Dr R.M. van Raalte, Maritimes Forestry Centre.

ADDRESS:

Dendron Resource Surveys Ltd.
Box 6493, Station J
Ottawa, Ontario K2A 3Y6
Canada

COOPERATION AGENCIES AND INVESTIGATORS (IF APPLICABLE):

DURATION:

Ongoing

APPROXIMATE COST (PER YEAR):

PROJECT OBJECTIVES/DESCRIPTION:

The recent revelation that there had been growth decline in Central European and Appalachian forests for some 20 or more years before the appearance of obvious growth disorders prompted the CFS to mount an especially sensitive dendrochronological study. In principle, stem samples are examined for the trends in annual incremental radial growth that have occurred over the life of the tree. If trees are aged from 50 years upwards, then trends are obtained that span periods that may include unusual climatic events as well as an upsurge in air pollution levels. The challenge is to separate out any such effects, so that a pollution effect might be identified.

The Project has four Phases. The goal of Phase I is to test methodologies and to analyze the effect of well-defined strong pollution sources on forest growth. This is a logical step leading to the assessment of the impact of long-range air pollution on forest growth on a continental scale.

Research during Phase I concentrated on forests near two pollution sources in Ontario. One of these is the iron-sintering plant at Wawa, which has been emitting SO₂ and other materials since 1939; the other is the smelter of Kidd Creek Mines near Timmins, which has been in operation since 1972. Seven sample plots were studied in detail in each pollution area. Plots were established upwind and downwind from the pollution sources and embraced situations exposed to a range of pollution loads.

Measurements and observations were also made in three areas outside the pollution zones. These "control areas" were used as standards for comparison. The study concentrated on white spruce but also included samples of jack pine, black spruce and balsam fir.

Project procedures involved the study of the growth rings of trees, using statistical procedures and dendrochronology as described by Fritts (1976) and others. A total of 1480 increment cores was collected and precisely measured. Computer files were established for data on sample plots, individual trees, and increment-core measurements. Information collected is compatible with other Canadian Forestry Service data bases, including sample plots of the Acid Rain National Early Warning System (Magasi, 1984). Results include an analysis of soil samples from each plot.

The main conclusions are as follows:

1. Tree growth at Wawa, as measured by a "Growth Effect Index", declined after the onset of pollution, except for very lightly polluted areas. Comparisons with control areas and with results for jack pine show that the decline in growth is due to pollution and not to other factors, such as spruce-budworm outbreaks. There is a remote possibility that growth increases on some lightly polluted areas are due to a fertilizer effect.

2. There were sharp declines in growth at Timmins during the period of pollution. However, these declines are also observed outside the pollution zone and there is a strong possibility that they are largely due to spruce-budworm outbreaks, possibly combined with climatic factors and pollution.

3. Analysis using "Growth Effect Indices" emerges as a very efficient tool. It is, however, essential that allowance be made for the age of the trees sampled, as was done in this project. The growth rate of trees declines with age and failure to make the necessary corrections produces misleading results, including invalid "evidence" of growth declines associated with pollution. However, no attempt was made to remove the effect of climatic factors, because the risk of inadvertently and simultaneously eliminating acid-rain effects was too high.

The study of "Growth Effect Indices" should be extended to cover replications by tree species, soil and site. Samples must be specifically selected to be designed to identify the causes of growth declines. One should build on Swedish experience, which shows that apparent relationships between growth and acid rain observed in one study may not be confirmed at a later date (Johnsson and Sundberg, 1972; Johnsson and Svensson, 1982).

4. There is evidence that, as a forest is exposed to pollution, growth patterns become more erratic. This is best measured by the coefficient of variation of annual increments (Table 7, p.44). The resulting pattern is a statistically defined symptom of the effect of pollution on growth.

5. Recent European research indicates that "missing" annual rings are one of the early signs of pollution damage. During the present project the methods for detecting missing rings were found to be effective, although time-consuming. However, the frequency of missing rings at Wawa and Timmins appears to be very low. Preliminary indications are that this is not a very promising approach in demonstrating the impact of pollution on growth.

6. If all tree ring data collected on this project are combined, then the "average chronology", the average trend of growth over time, shows characteristic and consistent patterns of high and low growth (Figure 18, p.53). Budworm outbreaks, climatic trends and pollution are among the suspected causes. Standard chronologies should be developed for the major acid-rain impact areas of Canada to assist in the identification of acid rain effects.

7. There is a surprisingly strong relationship between growth and SO₂ emissions at Wawa. The correlations between emission and annual growth several years later are in some cases unbelievably high (Figures 21, 22). The resulting correlograms may also indicate a more immediate impact on jack pine and a delay of several years before the effect on white spruce is most clearly defined.

The study of correlations between emission and growth should receive further attention. The results imply that some kind of periodicity or wave-like pattern can be used to describe the effect of pollution on the Canadian forest. The methods of correlation analysis that were tested should be used to define the relationship between tree growth over large areas and regional or continental statistics on acid rain emission.

-"-

LRTAP PROJECT DESCRIPTION

TITLE : Soil susceptibility to acid rain in New Brunswick

PRINCIPAL INVESTIGATOR :

NAME: H. van Groenewoud

PHONE: (506) 452-3581

AGENCY & DEPARTMENT: Canadian Forestry Service - Maritimes

ADDRESS: P.O. Box 4000
Fredericton, N.B.
E3B 5P7

COOPERATION AGENCIES
AND INVESTIGATORS
(IF APPLICABLE):

DURATION: 1989

APPROXIMATE COST (PER YEAR): 3K

PROJECT OBJECTIVES/DESCRIPTION

- 1) To determine the best possible method to evaluate the susceptibility of different forest soils.
- 2) To apply this method to different soils developed on different regolith systems to rate these soils for their susceptibility.

RESULTS EXPECTED : Information Report will be prepared.

LRTAP PROJECT DESCRIPTION

TITLE:

Effects of Aluminum, Oxalic Acid, Calcium and pH and the resulting speciation of aluminum on the growth and element uptake of black spruce

PRINCIPAL INVESTIGATOR:

NAME: Dr. P.A. Arp

AGENCY & DEPARTMENT:

University of New Brunswick
Department of Forest Resources

ADDRESS:

Bag Service Number 44555
Fredericton, N.B. E3B 6C2

COOPERATING AGENCIES AND INVESTIGATORS (IF APPLICABLE):

Canadian Forestry Service
Maritimes Forestry Centre
P.O. Box 4000
Fredericton, N.B. E3B 5P7
(M.K. Mahendrappa, Scientific Authority)

DURATION: June 1983 - June 1986

APPROXIMATE COST (1983-1986):

\$69,709.00

PROJECT OBJECTIVES/DESCRIPTION:

Several experiments were done to determine the effects of total concentrations of aluminum, oxalic acid, calcium, pH, and the resulting chemical speciation of aluminum in sand cultures on the growth and elemental uptake of black spruce (*Picea mariana* [Mill.] B.S.P.) seedlings.

The experiments with the black spruce seedlings revealed that increasing the total concentration of Al in the growth medium reduced plant growth as well as the P and Ca uptake of the shoots, but K uptake was enhanced. Additions of oxalic acid to the growth media had a negative effect on seedling growth while Al uptake was generally reduced, and K, Ca, P, and S uptake were increased. The Ca concentration and pH of the growth medium did not affect seedling growth. Seedling growth was negatively related to S uptake.

A detailed analysis of the chemical speciation of the growth media indicated that the chemical speciation of a given element affected not only its bio-availability but also the uptake of other elements. Individual chemical species, in addition, had distinct effects on specific seedling responses. Plant growth, however, was not related to chemical speciation of any of the elements studied.

Positively charged inorganic and organic Al species contributed to plant Al uptake and reduced Ca uptake while negatively charged organic Al species did not appear to be translocated to the plant shoots. Inorganic Al species, however, increased plant transpiration rate while organic Al species had no effect or reduced water uptake probably because of calcium oxalate precipitation on or in the roots.

Uptake of P was positively related to increased proportions of inorganic P species and an oxalo-Al-phosphate complex of net negative charge in the growth medium. This complex appeared to contribute to plant P absorption by a ligand exchange mechanism. Overall, the net charge of the chemical species rather than its chemical make-up appears to control its rate of uptake.

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P.A. Arp, 1983. "Modelling the effects of acid precipitation on soil leachates: A simple approach". *Ecol. Modelling* 19: 105-117.

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P.A. Arp, 1985. "Acid precipitation impacts on forest soils: H⁺-retention and Al-mobilization." A conference paper for "Acid rain - the current state of knowledge" sponsored by the Atlantic Provinces Council in the Sciences. Saint Mary's University, Halifax.

R. Ouimet and P.A. Arp, 1985. "Effect of organic and inorganic aluminum species on the early growth and elemental uptake of black spruce". *Water, Air, Soil Pollution* (to be submitted).

R. Ouimet and P.A. Arp, 1985. "Aluminum speciation in soil solutions: a quantitative example." *Water, Air, Soil Pollution* (to be submitted).

LRTAP PROJECT DESCRIPTION

TITLE: Early Diagnosis of Forest Decline arising from Air Pollutants using Physiological and Biochemical Indicators

PRINCIPAL INVESTIGATOR: (CFS)

NAME: K.E. Percy
E.S. Kondo
P.J. Rennie

AGENCY & DEPARTMENT:
Canadian Forestry Service

ADDRESS:
Maritimes Forestry Centre
P.O. Box 4000
Fredericton, N.B. E3B 5P7

COOPERATING AGENCIES AND INVESTIGATORS **(IF APPLICABLE):**

This is a cooperative project involving two Canadian agencies, the CFS and Ontario MOE, and several European authorities funded from the R&D Program of the European Economic Community (EEC).

The European authorities include:

Dr A.R. Wellburn
Department of Biological Sciences
University of Lancaster
Lancaster LA1 4YQ
England (Telephone 0524.65201)

Dr I.A. Nicholson
Institute of Terrestrial Ecology
Banchory Research Station
Hill of Brathens
Glassel
Banchory
Kincardineshire AB3 4BY
Scotland (Telephone 033.02.3434)

Dr F.T. Last
Institute of Terrestrial Ecology
Bush Estate
Penicuik
Midlothian EH26 0QB
Scotland (Telephone 031.445.4343)

Dr H.J. Jaeger
Institut für Pflanzenökologie
Justus-Liebig Universität
Giessen
Hesse
Federal Republic of Germany

Kevin E. Percy (CFS) is currently conducting studies at:
Long Ashton Research Station
Long Ashton
Bristol BS18 9AF
England (Telephone 0272.392181)

and is one of the points-of-contact linking the CFS with the Europeans.
The other CFS point-of-contact is P.J. Rennie.

DURATION: Continuing, with periodic review

APPROXIMATE COST (PER YEAR):
Not available

PROJECT OBJECTIVES/DESCRIPTION:

Background:

The project is highly relevant to the Canadian Early Warning Network. Several physiological and biochemical tests may be included in the regular testing protocols, but they may be too insensitive to indicate stress that precedes obvious growth disorders or visible foliar symptoms. As such they are costly and not very useful.

This project seeks to investigate whether there are one or more deep-seated physiological or biochemical properties that would be sensitive indicators, thereby enhancing the predictive value of the Early Warning System and avoiding considerable analysis. Such a sensitive biochemical indicator would be especially valuable in Canada, Scandinavia and Britain, where there are as yet no discernible widespread forest declines attributable to regional air pollution, rather than in Central Europe where the monitoring task is concerned with measuring obvious declines.

Objectives:

1. To develop predictive tests that can be used routinely to indicate the status of forest ecosystems in advance of the appearance of irreversible disorders. It is hoped the tests might indicate specific pollutants.
2. To study selected properties of a selection of tree species for:
 - (a) structural indicators,
 - (b) chemical indicators,
 - (c) metabolic indicators,that may be suitable for revealing and predicting the decline syndrome.

For this purpose tree material from a wide range of conditions is to be sampled, going from geographical areas considered unaffected through to areas considered heavily polluted. It is envisaged that such geographical areas can be found in several countries.

3. Diagnostic tests include:
 - (a) free-radical scavenging or disturbance-stress associated isoenzyme patterns,
 - (b) concentrations of B carotene relative to those of other pigments,
 - (c) changes in the emissions of hydrocarbons (ethane, ethylene, propane, propylene, etc.) from forest canopies,
 - (d) disruption of amino-acid patterns,
 - (e) changes in the composition and configuration of foliar cuticles

Discussions are still in progress on the various participants' roles.

TITLE: Chemistry of High Elevation Fog (CHEF) Program

PRINCIPAL INVESTIGATOR:

NAME: Dr Volker A. Mohnen, SUNY, Albany for the Environmental Protection Agency
Dr J.W.S. Young, Atmospheric Environment Service
Dr R.S. Schemenauer, Atmospheric Environment Service
Dr Gilles Robitaille, Canadian Forestry Service
Dr Denis Lachance, Canadian Forestry Service

AGENCY & DEPARTMENT:

See above

ADDRESS:

Laurentian Forestry Centre
Canadian Forestry Service
1080 route du Vallon, P.O. Box 3800
Ste Foy, Québec GLV 4C7

COOPERATION AGENCIES & INVESTIGATORS
(IF APPLICABLE):

See above

DURATION: Continuing, initially five years

APPROXIMATE COST (PER YEAR):

-

PROJECT OBJECTIVES/DESCRIPTION:

The background to the project is the serious decline and dieback occurring in high-elevation forests in the Appalachians and in Central Europe. It is known that such forests are exposed to a much higher than average impact by mists, fogs and clouds and that such aerosols are usually carriers of more acidity and pollutants than the ordinary atmosphere or precipitation, but there is a great dearth of details on the actual atmospheric properties of such high elevation situations. Only recently, for example, has it come to light that such forests are repeatedly exposed to phytotoxic concentrations of photochemical oxidants.

The existence of several sites throughout the Appalachians where meteorological and forestry observations have been in progress for several years has provided the opportunity to expand on the sites and to include new sites that increase the strength and usefulness of the network. United States sites include Mt Mitchell, Whiteface Mt, and Hubbard Brook, while extensions northwards into Canada include the Montmorency sector of the Laurentides Park as the main meteorological site, with Mont Tremblant and Roundtop Mountain in the Eastern Townships as sites where Early Warning Permanent Sample Plots have been established in the forest for continuous observation.

Clearly, for an inter-agency program, each agency will be conducting certain measurements and will be responsible for certain activities. For the CFS it is primarily the measurements on the forest vegetation and soils. Overall, though, all measurements are of interest and value to the CFS, whether they be the more conventional climatic parameters or the more specialized properties describing pollution characteristics.

1. TITLE: Hydrochemical investigation of a small forest watershed
2. AUTHOR: T.D. PHU
3. INSTITUTION: Laurentian Forest Research Centre

4. NAME OF GRANTING AGENCY: Canadian Forestry Service

5. NAME & ADDRESS OF GRANTING AGENCY: Laurentian Forest Research Centre

6. NAME OF GRANTING AGENCY: Laurentian Forest Research Centre

Gilles Robitaille
T.D. Phu
Robert Boutin

7. NAME OF GRANTING AGENCY: Laurentian Forest Research Centre
8. NAME OF GRANTING AGENCY: Laurentian Forest Research Centre
9. NAME OF GRANTING AGENCY: Laurentian Forest Research Centre
10. NAME OF GRANTING AGENCY: Laurentian Forest Research Centre

Laval University

11. NAME OF GRANTING AGENCY: Laurentian Forest Research Centre

12. NAME OF GRANTING AGENCY: Laurentian Forest Research Centre

13. NAME OF GRANTING AGENCY: Laurentian Forest Research Centre

This investigation takes place in a small forest watershed under typical forest climate conditions. The site is located 20 km north of Quebec in the Laurentian region of the Gaspésie Experimental Forest. More specifically, in the Lac Beauport watershed. The starting date was December 1980.

This study was designed to illustrate the possibility for different water perturbations of the input of ions via precipitation, in a

LRIAP PROJECT DESCRIPTION

TITLE 1. Biogeochemical investigations in a boreal forest ecosystem

PRINCIPAL INVESTIGATOR

NAME Dr Gilles Robitaille PHONE 418 648-5826

AGENCY & DEPARTMENT Canadian Forestry Service

ADDRESS Laurentian Forest Research Centre
1055 PEPS Street
C.P. 3800, Ste. Foy
Que.
G1V 4C7

COOPERATION AGENCIES
AND INVESTIGATORS
(IF APPLICABLE) Laval University, Montmorency Experimental
Forest, Inland Waters Directorate Quebec
Region, Atmospheric Environment Service

DURATION Long term continuous

APPROXIMATE COST (PER YEAR) 40 K

PROJECT OBJECTIVES/DESCRIPTION

This investigation takes place in a balsam forest ecosystem under typical boreal climate conditions. The site is located 80 km north of Quebec in the Laurentide reserve at the Montmorency Experimental Forest. More specifically at the Lake Laflamme catchment. The starting date was December 1980.

This study was designed to illucidate the potential for nutrient cycle perturbation of the input of ions via precipitation, in a

boreal forest ecosystem. The approach used monitors, the cycle of various acidifying and nutrient ions throughout the hydrological and biological pathways. The biological pathway means return of nutrient elements via litter fall, the storage of these elements in the vegetation biologically active soil. The hydrological pathway means input to the system via wet deposition i.e. rain and snow (fog and dry deposition to be considered in the future), movement of ions within the forest and the soil systems and the export of these ions out of the systems.

Anticipated results: this investigation will give us much needed information on:

- nutrient input via long range transported rain and snow to a boreal forest ecosystem;
- nutrient stores and movements within the system;
- potential acidification and nutrient export for this system;
- mobilization of nutrient in a podzol in relation to nutrient input via through fall;
- on nutrient distribution from the organic horizon to the mineral soil;
- nutrient deficiency;
- long term fluctuations of nutrient cycles for a coniferous forest;
- the potential effect on biomass formation of observed anomalies in the above.

* * *

LRTAP PROJECT DESCRIPTION

TITLE 2. Nitrate, sulphate and hydrogen saturation of an acidic soil (podzol)

PRINCIPAL INVESTIGATOR

NAME Dr Gilles Robitaille PHONE 418 648-5826
Robert Boutin 418 648-5825

AGENCY & DEPARTMENT Canadian Forestry Service

ADDRESS Laurentian Forest Research Centre
1055 PEPS Street
C.P. 3800, Ste. Foy
Que.
G1V 4C7

COOPERATION AGENCIES AND INVESTIGATORS (IF APPLICABLE)

DURATION 3 years

APPROXIMATE COST (PER YEAR) 7 K

PROJECT OBJECTIVES/DESCRIPTION

These series of laboratory experiments were designed to give information on nutrient depletion from the soil exchange sites. In a phase I experiment a gradient of SO_4^{2-} and H^+ was applied to a reconstituted profile. In a phase 2, experiment NO_3 was added to the former. The amendments were added to organic horizons on the one hand and inorganic horizons supported by lower mineral horizons on the other hand. Soils were analysed before and after amendments. Leachates were analysed on a weekly basis.

Anticipated results: These experiments will give us information on:

- the depletion of nutrients from a low nutrient acid podzol for various loadings of SO_4^{2-} , NO_3^- , and H^+ ;
- mobilization of nutrient in a podzol due to the amendment;
- nutrient movement from mineralization potential of the organic horizons;
- leaching potential of a podzol;
- mobilization of Al^3 , Mg^{2+} and Mn^{2+} ;
- modifications in soil exchange acidity, internal acidification.

* * *

LRTAP PROJECT DESCRIPTION

TITLE 3. Changes in the fertility status of a podzol supporting jack pine

PRINCIPAL INVESTIGATOR

<u>NAME</u>	Dr Gilles Robitaille	<u>PHONE</u>	418 648-5826
	T.D. Phu		418 648-5839
	Robert Boutin		418 648-5825
<u>AGENCY & DEPARTMENT</u>	Canadian Forestry Service		

ADDRESS Laurentian Forest Research Centre
1055 PEPS Street
C.P. 3800, Ste. Foy
Que.
G1V 4C7

COOPERATION AGENCIES AND INVESTIGATORS (IF APPLICABLE)

DURATION 2 years

APPROXIMATE COST (PER YEAR) 4 K

PROJECT OBJECTIVES/DESCRIPTION

This project was designed to benefit from the data obtained from a study done in 1977 on soil fertility and needle nutrient status of jack pine. In 1985, a resampling of sites was done. Fertility comparisons are to be made. Further sampling is to be done in 1986.

Anticipated results: evolution of soil fertility over time related to factors such as precipitation, temperature and stand evolution.

AGENCY & DEPARTMENT: Canadian Forestry Service

PROJECTS: Laurentian Forest Research Centre
* * *
J. P. Bouché, MSc, PhD
Gen.
517 407

COOPERATION AGENCIES AND INVESTIGATORS (IF APPLICABLE): CFS sponsored by Dr. A. J. Bouché, Dr. C. Bouché, Dr. P. Lefebvre
Laval University

DURATION: 2 years 1983-85

APPROXIMATE COST OVER TIME: \$0

PROJECT DESCRIPTION:

Both field and laboratory experiments are used to determine effects on the mycorrhizae. In addition to a study on the effects of mycorrhizae on the decomposition and nutrient recycling from the soil and the forest litter, the latter observations are related to the forest production. In the laboratory, mycorrhizal fungi are used to study the effects of various factors on the growth of the mycorrhizae and the forest production.

TRIAP PROJECT DESCRIPTION

TITLE 4. Effects of Al, Mn, Mg gradients under various acidity regimes on the development - function of ectomycorhyza of balsam fir

SCIENTIFIC AUTHORITY

NAME Dr Gilles Robitaille PHONE 418 648-5826

AGENCY & DEPARTMENT Canadian Forestry Service

ADDRESS Laurentian Forest Research Centre
1055 PEPS Street
C.P. 3800, Ste. Foy
Que.
G1V 4C7

COOPERATION AGENCIES
AND INVESTIGATORS
(IF APPLICABLE) CFS sponsorship to Dr. A. Fortin, Dr.
C. Camire, Dr. Y. Laflamme
Laval University

DURATION 2 years 1985-86

APPROXIMATE COST (PER YEAR) 90 K

PROJECT OBJECTIVES/DESCRIPTION

Both field and laboratory experiments are used to observe effects on the mycorhyza. An adjunct is a study on the effects of organic matter decomposition and nutrient leaching from the soil profile. The latter observations are related to the former potential effects. In the laboratory mycorrhizal inoculated roots are used as experimental material while in the field mycorrhizal free transplants are used for growth effect observations.

Anticipated results: the study should give us information on:

- synergism between acidity and metal gradients on development and function of mycorrhiza, that would affect the growth of balsam fir;
- treatment effect on the absorption of phosphorus, potassium, calcium and magnesium;
- treatment effect on organic matter decomposition and hence possible perturbation of the cycling of nutrients need for growth.

* * *

This is a collaborative monitoring effort for the detection of IRFA symptoms in Canada's forest and supervised by FICIS. A standardized methodology manual has been developed by FICIS/IRFA scientists and is in use across the nation. On a regional basis, the involvement of IRFA scientists is in the soil and vegetation sampling and analysis sectors. In these sectors, base line data are collected and reviewed every 5 years. In the IRFA program, permanent plots are maintained 127 in Quebec region to monitor

LRTAP PROJECT DESCRIPTION

TITLE 5. Acid Rain National Early Warning System (ARNEWS-
Quebec Region)

PRINCIPAL INVESTIGATOR

NAME Dr Gilles Robitaille, T.D. Phu PHONE 418 648-5826
& R. Boutin

AGENCY & DEPARTMENT Canadian Forestry Service

ADDRESS Laurentian Forest Research Centre
1055 PEPS Street
C.P. 3800, Ste. Foy
Que.
G1V 4C7

COOPERATION AGENCIES AND INVESTIGATORS (IF APPLICABLE)

A collaborative effort by two Canadian Forestry Service national programs. These are Long Range Transport of Air Pollution program (LRTAP) and the Forest Insect and Disease Survey program (FIDS). Dr. D. Lachance is FDS chief in Quebec region.

DURATION

APPROXIMATE COST (PER YEAR) Long term continuous
7 K

PROJECT OBJECTIVES/DESCRIPTION

This is a collaborative monitoring effort for the detection of LRTAP symptoms in Canada's forest and supervised by FIDS. A standardized methods manual has been developed by FIDS/LRTAP scientists and is in use across the nation. On a regional basis, the involvement of LRTAP scientists is in the soil and vegetation sampling and analyses sectors. In these sectors, base line data are collected and reexamined every 5 years. In the ARNEWS program, permanent plots are maintained (25 in Quebec region) to monitor:

- the condition & changes in the condition of the forest stand;
- the presence & fluctuation of biotic and abiotic factors that affect the condition of the forest;
- the changes & symptoms that indicate factors not attributable to the above that would be early signs of LRTAP damage;
- effects of LRTAP on the condition of the various economically important tree species.

* * *

This project is a collaborative effort between researchers at Laval University and CFS. The project on nutrient movement and storage was initiated by D. Bernier, CFS researcher who then sought by B. Bernier to expand on completed low nutrient cycling and storage patterns. The project is similar in objectives to that described in the phosphorus movement project but on a more reduced scale.

LRIAP PROJECT DESCRIPTION

TITLE 6: Nutrient movement in a declining sugar maple stand
in Quebec

PRINCIPAL INVESTIGATOR

NAME Dr Gilles Robitaille PHONE 418 648-5826

AGENCY & DEPARTMENT Canadian Forestry Service

ADDRESS Laurentian Forest Research Centre
1055 PEPS Street
C.P. 3800, Ste. Foy
Que.
G1V 4C7

COOPERATION AGENCIES
AND INVESTIGATORS
(IF APPLICABLE) Dr. B. Bernier
Laval University

DURATION 3 years

APPROXIMATE COST (PER YEAR) 3 K

PROJECT OBJECTIVES/DESCRIPTION

This project is a collaborative effort between researchers at Laval University and CFS. The project on nutrient movement and storage was initiated by B. Bernier. CFS expertise was then sought by B. Bernier in order to complete the nutrient cycling and storage picture. The project is similar in methodology to that described in the biogeochemical investigation project but on a much reduced scale.

Anticipated results: data on nutrient movement and storage perturbations due to LRTAP.

* * *

Major Data Series Research Results

- 1. A. Monitoring
- 2. B. Testing
- 3. C. Simulation
- 4. D. Design
- 5. E. Modeling

Major Findings of the LRTAP Study

1974:

Report of the Committee on Forest Research

Principal Investigators:

Chair: Dr. L.A. Morrison Chair: 1974-1975

Member: Dr. J. Foster Member: 1974-1975
Member: Dr. J. Nicolson Member: 1974-1975

Member: Dr. G.D. Hogan Member: 1974-1975
Member: Dr. R.D. Whitney Member: 1974-1975

Member: Dr. J. Foster Member: 1974-1975
Member: Dr. J. Nicolson Member: 1974-1975
Member: Dr. G.D. Hogan Member: 1974-1975
Member: Dr. R.D. Whitney Member: 1974-1975

Member:

Great Lakes Forest Research Centre

Member:

Member:

I.K. Morrison

N.W. Foster

J.A. Nicolson

G.D. Hogan

R.D. Whitney

Ontario Ministry of Natural Resources

LRTAP PROJECT DESCRIPTION

Title: Impact of Acid Deposition on Forest Productivity

Principal Investigator

Name: Dr. I.K. Morrison Phone: (705) 949-9461

Agency and Department: Department of Agriculture
Canadian Forestry Service

Address: Great Lakes Forest Research Centre
P.O. Box 490
Sault Ste. Marie, Ontario
P6A 5M7

Cooperation Agencies and Investigators (If Applicable): DOE, Inland Waters Directorate
DFO, Great Lakes Biolimnology Laboratory
(Dr. J.R.M. Kelso)
OMNR, Sault Ste. Marie District

Duration: 1980-1987

Approximate Cost (Per Year): \$70,000.00 per annum, including salaries

Project Objectives/Description:

- a) To elucidate the influence of atmospheric deposition of acidifying substances upon production and turnover processes within the vegetation of forest ecosystems.
- b) To elucidate the modifying influence of the vegetation of forest ecosystems on precipitation properties
- c) To participate in the development of process models involving forest growth and biogeochemical processes
- d) Study is being carried out on three main study sites in old-growth hard maple-yellow birch woods, Algoma District, Ontario, and closely coordinated with those of Drs. N. Foster and J. Nicolson. Growth is being measured on large numbers of PSPs; correlation with soil chemical factors will be attempted. Standing crop biomass and bioelement reserves have been estimated. Transfer in litter is being ascertained by studies of litterfall and litter chemistry (transfer in by throughfall, stemflow being studied by colleagues). Studies of litter decomposition rate in relation to acid treatment are being undertaken.

Data, together with those of colleagues, will be used to test and calibrate processes relating acid deposition and productivity of northern Ontario old-grown hardwood forest.

LRTAP PROJECT DESCRIPTION

Title: Effects of Simulated Acid Precipitation on Composition of Percolate from Reconstructed Profiles of Two Northern Ontario Forest Soils

Principal Investigator

Name: Dr. I.K. Morrison Phone: (705) 949-9461

Agency and Department: Department of Agriculture
Canadian Forestry Service

Address: Great Lakes Forest Research Centre
P.O. Box 490
Sault Ste. Marie, Ontario
P6A 5M7

Cooperation Agencies and Investigators (If Applicable):

Duration: 1977-1987

Approximate Cost
(Per Year): \$5,000.00 per annum, including salaries

Project Objectives/Description:

- a) To compare products of leaching, chiefly bases, H^+ -ion and SO_4^{--} -ion from reconstructed profiles of two northern Ontario forest soils under different regimes of dilute H_2SO_4 addition
- b) To compare effects of different dilute H_2SO_4 addition on soil chemical properties
- c) Two soils (a podzol and a brunisol, both from beneath mid-age jack pine forest) were reconstructed into 100 cm high column lysimeters. Dilute H_2SO_4 ranging in pH from 5.6 to 2.0, but at environmentally realistic rate, i.e., 1000 mm/annum has been dripped to each of the 24 columns weekly since mid-1977. Volumes are measured weekly; monthly the following are determined on the percolates: pH, specific conductance, K^+ , Ca^{++} , Mg^{++} , Na^+ , several trace metals, SO_4^{--} . At the culmination of the experiment soil will be analysed by horizons.

Time course of SO_4^{--} retention, then movement is followed in relation to loading together with time-course of cation transport.

LRTAP PROJECT DESCRIPTION

Title: Impact of Acid Deposition on Forest Soils

Principal Investigator

Name: Dr. N.W. Foster Phone: (705) 949-9461

Agency and Department: Department of Agriculture
Canadian Forestry Service

Address: Great Lakes Forest Research Centre
P.O. Box 490
Sault Ste. Marie, Ontario
P6A 5M7

Cooperation Agencies and Investigators OMNR, Sault Ste. Marie District
(If Applicable): DOE, Inland Waters Directorate
DFO, Great Lakes Bioliminology Laboratory

Duration: 1980-1990

Approximate Cost
(Per Year): \$37 K + 1 PY (Prof) and 2 PY (Tech)

Project Objectives/Description:

- a) To elucidate the influence of atmospheric deposition of acidifying substances upon soil chemical properties and processes
- b) To elucidate the modifying influence of forest soil on properties of percolating acid precipitation

Ion fluxes in precipitation, throughfall, forest floor percolate, stem-flow, and streamflow, since 1980, and mineral soil percolate, since 1982, have been determined in a small catchment with shallow till supporting sugar maple-yellow birch forests at Turkey Lakes Watershed. Nutrients, major ions, and trace metals were determined on an 'event basis' through 1984 and monthly since then. Field studies have been supported by laboratory examination of the reactions of nitrogen and sulphur in soil.

LRTAP PROJECT DESCRIPTION

Title: Impact of Acid Deposition on Forest Hydrologic Processes

Principal Investigator

Name: Dr. J.A. Nicolson Phone: (705) 949-9461

Agency and Department: Department of Agriculture
Canadian Forestry Service

Address: Great Lakes Forest Research Centre
P.O. Box 490
Sault Ste. Marie, Ontario
P6A 5M7

Cooperation Agencies and Investigators (If Applicable): DOE, Inland Waters Directorate
OMNR, Sault Ste. Marie District

Duration: July 1980 to 1990

Approximate Cost (Per Year): \$37 K

Project Objectives/Description:

To elucidate the influence of atmospheric deposition of acidifying substances upon the hydrochemical cycle and the export of elements from forested catchments through the collection of water samples and the measurement of runoff volumes.

In an old-growth hard maple-yellow birch watershed on shallow till soils (Turkey Lake Forest Watershed).

- a) Fourteen small (2-63 ha) watersheds have been established and are sampled on a regular basis.
- b) Six additional watersheds are sampled and flow measured periodically.
- c) Twelve plots have been established in one basin where sampling is done to study the partitioning of both the volume and chemistry of gross precipitation within the forest ecosystem.
- d) Chemical analysis of all samples is carried out in the Great Lakes Forest Research Centre laboratory.

LRTAP PROJECT DESCRIPTION

Title: Effects of Environmental Chemistry on Tree Form and Function in Natural and Managed Systems with Emphasis on Impacts of Atmospheric Pollution

Principal Investigator

Name: Dr. G.D. Hogan

Phone: (705) 949-9461

Agency and Department:

Department of Agriculture
Canadian Forestry Service

Address:

Great Lakes Forest Research Centre
P.O. Box 490
Sault Ste. Marie, Ontario
P6A 5M7

Cooperation Agencies and Investigators (If Applicable):

OMNR Research Branch, OMNR Sault Ste. Marie and
Blind River Districts

Duration:

1984-1990

Approximate Cost
(Per Year):

20 K + 1 PY (Prof) and 1 PY (Tech)

Project Objectives/Description:

- a) To study the direct physiological response of forest species to simulated acid rain
- b) To study the effects of simulated acid rain on growth, carbon fixation and the leaching of nutrients from foliar material.

LRTAP PROJECT DESCRIPTION

Title: Effects of Increase in Rain Acidity on Tree Diseases

Principal Investigator

Name: Dr. R.D. Whitney Phone: (705) 949-9461

Agency and Department: Department of Agriculture
Canadian Forestry Service

Address: Great Lakes Forest Research Centre
P.O. Box 490
Sault Ste. Marie, Ontario
P6A 5M7

Cooperation Agencies and Investigators (If Applicable):

Ontario Ministry of Natural Resources

Duration: 1985-1989

Approximate Cost (Per Year):

\$10,000 + .3 PY (Prof) and .4 PY (Tech)

Project Objectives/Description:

To determine the effects of simulated acid rain on selected tree diseases by:

- a) Examining the infection success and growth rate of *Armillaria* sp. inoculated in the roots of trees exposed to simulated rainfall of varying pHs
- b) In the same controlled experiment to monitor other diseases and mycorrhizae occurring naturally on the treated trees.

On an area of approximately 3 ha near Randolph Lake in Rose Township, some 80 km east of Sault Ste. Marie, 75 balsam fir saplings, 2 m high, which have been inoculated with *Armillaria obscura*, are being treated bi-weekly to simulated rain of 3 pHs. Sixty of the trees are protected from natural precipitation with plastic 'tents.' Infection success and rate of growth of *A. obscura* in the roots will be determined after two growing seasons.

Northern Forest Research Centre

S.S. Sidhu

B.H. Moody

D. G. Maynard

P.A. Addison

P.A. Addison

D. Wotton

Manitoba Environment

Canterra Energy Ltd.
Gulf Canada

- Canterra Energy Ltd.
Gulf Canada

LRTAP PROJECT DESCRIPTION

TITLE

Acid Rain Natinal Early Warning System (ARNEWS)

PRINCIPAL INVESTIGATOR

NAME: B.H. Moody, S.S. Sidhu

PHONE: (403) 435-7210

AGENCY & DEPARTMENT: Canadian Forestry Service

ADDRESS: Northern Forest Research Centre
5320 - 122 Street
Edmonton, Alberta
T6H 3S5

COOPERATION AGENCIES AND INVESTIGATORS (IF APPLICABLE):

D. Wotton,
Manitoba Environment

DURATION: 25+ years

APPROXIMATE COST (PER YEAR): \$16K excluding salaries

PROJECT OBJECTIVES/DESCRIPTION

1. To detect the possible damage to forest trees and soils caused by acid rain or to identify the damages sustained by the forest (trees and soils) which are not attributable to natural causes or management practices.
2. Long-term monitoring of vegetation and soils to detect future changes attributable to acid deposition and other air pollutants in representative forest ecosystem.

IRTAP PROJECT DESCRIPTION

TITLE

Assessment of air pollution impact on forest systems

PRINCIPAL INVESTIGATOR

NAME: Paul A. Addison
Doug G. Maynard

PHONE: (403) 435-7210

AGENCY & DEPARTMENT: Canadian Forestry Service

ADDRESS: Northern Forest Research Centre
5320 - 122 Street
Edmonton, Alberta
T6H 3S5

COOPERATION AGENCIES Canterra Energy Ltd.
AND INVESTIGATORS Gulf Canada
(IF APPLICABLE):

DURATION: 5 year 1981-1986

APPROXIMATE COST (PER YEAR): \$70K excluding salaries

PROJECT OBJECTIVES/DESCRIPTION

- 1) Describe and assess changes in the forest ecosystem as a result of two sour gas plants in west-central Alberta (in cooperation with Dr. D.G. Maynard).
- 2) Determine the mechanism of elemental sulfur dust impact to the soil plant system (Maynard and Addison)

Pacific & Yukon Forest Research Centre

D.S. Lacate

J.P. Senyk

G.A. van Sickle

M.C. Feller

University of British Columbia

M. Walmsley

Pedology Consultants

B.C. Environment

Alberta Environment

Saskatchewan Environment

Manitoba Environment

B.C. Ministry of Forests

LRTAP PROJECT DESCRIPTION

TITLE Comparison of tree ring chemistry and changes in growth rates in areas impacted by "Acid Rain" in southwestern British Columbia.

PRINCIPAL INVESTIGATOR

NAME: John P. Senyk

PHONE: (604) 388-0688

AGENCY & DEPARTMENT: Pacific Forestry Centre,
Canadian Forestry Service
506 West Burnside Road
ADDRESS: Victoria, B. C. V8Z 1M5.

COOPERATION AGENCIES
AND INVESTIGATORS
(IF APPLICABLE):

B. C. Environment

DURATION: 5 years

APPROXIMATE COST (PER YEAR): \$5800.

PROJECT OBJECTIVES/DESCRIPTION

To identify changes in tree growth rates, if any, and analyze growth rings for trace element accumulation and wood density - derive historic deposition patterns and compare or relate these to any changes in growth rates.

LRTAP PROJECT DESCRIPTION

TITLE Yukon Soils and Geology Sensitivity Mapping.

PRINCIPAL INVESTIGATOR

NAME: John P. Senyk

PHONE: (604) 388 0688

AGENCY & DEPARTMENT: Pacific Forestry Centre
Canadian Forestry Service
506 West Burnside Road
ADDRESS: Victoria, B. C. V8Z 1M5.

COOPERATION AGENCIES AND INVESTIGATORS (IF APPLICABLE):

B.C. Ministry Environment - J. Weins
Alberta Environmenta - N. Holowaychuk
Saskatchewan Environment - Glen Padbury
Manitoba Environment - Dave Wotton
Lands Directorate - C. Rubec

DURATION: 3 years (.6 P/Y) total

APPROXIMATE COST (PER YEAR): \$2000.

PROJECT OBJECTIVES/DESCRIPTION

Produce maps of:

- (1) Potential of soil and geology to reduce the acidity of incoming acidic deposition (impacting aquatic resource).
- (2) Soil sensitivity to acidic deposition (impacting vegetation).

LRTAP PROJECT DESCRIPTION

TITLE Analysis of Existing Ecosystem Chemistry Data Pertinent to the ARNEWS
Plot Established Near Spur 17 in the UBC Research Forest.

PRINCIPAL INVESTIGATOR

NAME: M.C. Feller

PHONE: (604) 228-3729

AGENCY & DEPARTMENT: Faculty of Forestry

ADDRESS: UBC, Vancouver, B.C.

COOPERATION AGENCIES CFS Contract (Scientific Authority: G.A. Van Sickle.
AND INVESTIGATORS
(IF APPLICABLE):

DURATION: On-going.

APPROXIMATE COST (PER YEAR): \$10,000

PROJECT OBJECTIVES/DESCRIPTION

To supply CFS with analyses of long term soil, water and precipitation chemistry gathered adjacent to ARNEWS plot.

LRTAP PROJECT DESCRIPTION

TITLE Acid Rain Research and Monitoring Studies in B. C.,
Yukon and U.S. Pacific Northwest.

PRINCIPAL INVESTIGATOR

NAME: M. Walmsley

PHONE: (604) 386-1114

AGENCY & DEPARTMENT: Pedology Consultants

ADDRESS: Victoria, B.C.

COOPERATION AGENCIES CFS Contract (Scientific Authority, D.S. Lacate)
AND INVESTIGATORS
(IF APPLICABLE):

DURATION: one year (completed)

APPROXIMATE COST ~~(PER YEAR)~~: \$2,500

PROJECT OBJECTIVES/DESCRIPTION

To review on-going and planned studies. Report completed and circulated to cooperating agencies in B. C. and U.S. Pacific Northwest.

LRTAP PROJECT DESCRIPTION

TITLE Analysis of Foliar and Soil Samples for ARNEWS" Plots.

PRINCIPAL INVESTIGATOR Pacific Soil Analysis Inc.

NAME:

PHONE:

AGENCY & DEPARTMENT:

ADDRESS: Vancouver

COOPERATION AGENCIES CFS Contract (Scientific Authority J.P. Senyk)
AND INVESTIGATORS
(IF APPLICABLE):

DURATION: one year (completed)

APPROXIMATE COST (PER YEAR): \$4000.

PROJECT OBJECTIVES/DESCRIPTION

To supply the specified analyses for foliar and soil samples for
3 ARNEWS plots established in 1984-85.

LRTAP PROJECT DESCRIPTION

TITLE FOREST INSECT AND DISEASE SURVEY (FIDS) (ARNEWS Plot Monitoring).

PRINCIPAL INVESTIGATOR

NAME: G. A. Van Sickle

PHONE: 604 (388-0600)

AGENCY & DEPARTMENT: Pacific Forestry Centre,
Canadian Forestry Service
506 West Burnside Road,
ADDRESS: Victoria, B. C.
V8Z 1M5.

COOPERATION AGENCIES
AND INVESTIGATORS
(IF APPLICABLE):

B. C. Ministry of Forests
B. C. Ministry of Environment

DURATION: On-going.

APPROXIMATE COST (PER YEAR): \$10,000

PROJECT OBJECTIVES/DESCRIPTION

The objective of the program is to obtain baseline knowledge of the concentrations of foliar and soil elements, foliar and tree condition including insect and disease levels, and tree growth followed-up by the detection and monitoring of possible changes.

Nine nationally standardized forest plots have been established as part of the ARNEWS program in B.C. An additional 6 plots will be established in 1986.

To obtain a more immediate assessment of the condition of the forest in B.C., subjective observations were undertaken at 417 of the province-wide permanent sample sites.

CAIF085594

CANADIAN FORESTRY Service

AUTHOR

- Long-Range Transport of

TITLE

non-Pollutants in Air Pollution

RESOURCE CENTRE
INST. FOR ENVIRON'L. STUDIES
UNIVERSITY OF TORONTO



